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ABSTRACT

The notion that autistic children process information predominantly by strategies of the right cerebral hemisphere from birth, and unless unusual events occur, continue to be right hemisphere processors throughout their life, is examined. Evidence that suggests that cerebral dominance may be present at birth in normal humans, and that for normal humans each hemisphere of the cerebral cortex may be responsible for different kinds of information processing is presented as the context from which the new model of autistic development emerges. Two preliminary experiments involving listening preferences of autistic and normal Ss (with mean ages ranging from 5 to 10 years) are cited as having tested and supported the hypothesis that the right cerebral hemisphere is more active than the left hemisphere in autistic children. Implications of the model for diagnosis and treatment of autism are presented. (Author)

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REPORT NO. 64

JULY 1977

CEREBRAL ASYMMETRY AND THE DEVELOPMENT OF INFANTILE AUTISM

E. G. BLACKSTOCK

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The notion that autistic children process information predominantly by strategies of the right cerebral hemisphere from birth, and unless unusual events occur continue to be right hemisphere processors throughout their life spans, is examined. Evidence that suggests that cerebral dominance may be present at birth in normal humans, and that for normal humans each hemisphere of the cerebral cortex may be responsible for different kinds of information processing is presented as the context from which this new model of autistic development emerges. Two preliminary experiments involving listening preferences of autistic and normal subjects have tested and supported the hypothesis that the right cerebral hemisphere is more active than the left hemisphere in autistic children. Implications of the model for diagnosis and treatment of autism are presented.

Early infantile autism, first described in detail by Kanner (1943) and subsequently and extensively by others (Creak, 1964; Rimland, 1964; Rutter, 1966, Wing, 1966), has an initial or precipitating cause and a history of ontological events which guide and determine the development and expression of the syndrome. Neither the initial nor the developmental causes are yet known. Indeed, researchers have barely begun to agree on the nature of the syndrome. Some consensus, however, has been reached on several aspects of autism. There seem to be two distinct kinds of autistic people: 1. a "congenital" group with onset from birth, and; 2. a group in which a period of normal development precedes any noticeable symptoms (Creak, 1951; Goldfarb, 1970; Harper & Williams, 1974; Kolvin, 1971; Rutter & Lockyer, 1987). There seems to be growing consensus that among all the children diagnosed autistic is a large group for which a combination of genetic and biological factors are responsible as the initiating agents of autistic development (Boullin & O'Brien, 1972; Delacato, 1974; Himwich, Jenkins, Fujimori, Narasimhaçgari & Ebersole, 1972; Hingtgen & Bryson, 1972; Rutter, 1974; Yuwiler, Ritvo, Bald, Kipper and Koper, 1971; Walker-Smith & Andrews, 1972). This group is, of course, the "congenital" group mentioned above. Rutter (1974) further delineates this group in his recent and extensive review of psychological investigations of the causes and characteristics of autism which concludes that "a cognitive deficit is probably a sufficient as well as necessary factor for the development of the basic symptoms of autism." Rutter goes on to point out that what is yet unknown and should be the focus of further study is the precise character of the cognitive deficit and the neurophysiological causes thereof. In other words, the initial or precipitating cause of early infantile autism may be genetic or biological in nature and the

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developmental events the result of the interaction of the initial biological or structural state and the subsequent "cognitive" and "perceptual" experiences.

What the neurobiological state of autistic children, or for that matter, any child, at birth is is far from being known. However, recent research in the field of cerebral cortex functioning has suggested to me a possible initial cerebral organization which could account for the occurrence of developmental events or experiences which would lead to autistic behaviour. The most relevant notions are that in normal humans cerebral dominance may be present at birth (Entus, 1975; Harris, 1975; and Kinsbourne, 1974) and that for normal humans each hemisphere of the cerebral cortex may be responsible for quite divergent kinds of information processing. The plausibility of the notion that autistic children are predominantly right hemisphere processors at birth and, unless unusual events occur, continue to be right-hemisphere processors throughout their life span, will be examined here.

There is a great deal of literature, reviewed below, which has established that normally language, analytic or propositional information is processed by the left hemisphere and other kinds of nonverbal, holistic or apositional (Bogen, 1969) information is processed by the right hemisphere. The following review will discuss the literature regarding cerebral lateralization of function, and then discuss what literature there is to support the widely observed phenomenon that autistic children are proficient at behaviours associated with the right hemisphere and almost never exhibit behaviour associated with the left hemisphere, even after intensive training.

The notion that the two cerebral hemispheres in man carry out different kinds of mental processes is well supported and widely accepted. While the exact nature of the lateralized processes (Bevins & Chiarello, 1974; Bogen, 1969) and the degree of exclusivity (Gazzaniga & Sperry, 1967; Zangwill, 1967) of any identified process from either side is a matter of active controversy, some broad classes of processes have been well established as being lateralized to one side or the other. The most thoroughly substantiated finding is that language is lateralized to the left hemisphere. Zangwill's (1967) review of five studies involving 1,942 subjects with lesions of the right or left hemisphere, as well as the data from cases of cerebral commissurotomy, concludes that while the right hemisphere is implicated in some aspects of language processing the left hemisphere is mainly responsible for processing language, especially its analytic and sequential aspects. Several recent studies have confirmed these earlier findings. Cohen, Noblin, Silverman, and Penick (1968) administered a verbal paired associates task and visuographic learning task to 24 right handed females both before and five to eight hours after unilateral shock therapy. They found that language functions were more disturbed when the shock was administered to the left, and that the visuographic functions were more disturbed after shock to the right side. Buchsbaum and Fedio (1970) measured evoked cortical potentials over the right and left occipital cortexes of 8 male and 8 female undergraduates in response to verbal and nonsense stimuli. They found stable waveform activity over

the right for the nonsense, or nonverbal, material, concluding that their "data confirmed and extended a series of physiologic (Buchsbaum & Fedio, 1969; Eason, et al., 1967; Lansing, 1964) and behavioural (Bryden, 1965; Kimura, 1961; Milner & Teuber, 1968) findings that assymetric cerebral functions . . . are reflected in the human evoked cortical potential." Fedio and Buchsbaum (1971) also found of 11 epileptic patients who had undergone left (5 cases) or right (6 cases) anterior temporal lobectomies for the relief of intractable seizures that those patients with left hemisphere lobectomies performed more poorly on tachistoscopic recognition test of verbal material than did patients with right hemisphere lobectomies, and that those with right hemisphere lobectomies did more poorly on nonverbal tasks. Their obvious conclusion was that "unilateral lesions are associated with selective cognitive defects." Lansdell (1973), conducting both pre and post operative tests with 156 patients with unilateral temporal lobes removed and unilateral thalamotomies, found that operations on the left hemisphere disturbed the ability to perform popular word associations while right hemisphere operations did not. Another major line of research is that making use of dichotic listening in which competing information is played simultaneously to both ears followed by tests of recall or recognition memory. Virtually all of these studies accept the conclusion of Tunturi (1946) and Rosenzweig (1951) that contralateral auditory connections are functionally more proficient, more immediate and preferred to ipsilateral ones. The most widely accepted explanation for this hypothesis is that the extra length of the pathway is not sufficient to account for the extra amount of time an ipsilateral message takes. (His explanation of the greater efficiency of contralateral connections is described below.) Regardless of the cause of the stronger contralateral connections all dichotic listening tests showed a right ear (left hemisphere) preference for verbal material (Chase, 1967; Gordon, 1970; Kimura, 1961; Shankweiler, 1966).

While the left hemisphere is clearly implicated in playing the major role in verbal processing, less is known about right hemisphere processes. The earliest studies regarding auditory processing in the right and left hemispheres were those by Milner (1962) and Hecaen (1962). Milner's classic paper reports the results of both pre and post operative tests of patients having right or left hemisphere lobectomies on six items in the Seashore (Saetveit, Lewis, & Seashore, 1940) Measure of Musical Talents. Her results showed that right temporal lobectomies negatively affected performance on the timbre and tonal memory tests, while left temporal lobectomies had virtually no effect. Hecaen (1962, p. 218) also observed amusia following lesions of the right hemisphere but not of the left. Kimura (1964), searching for the neural substrate for musical ability, dichotically presented spoken digits and classical melodies (e.g., by Mozart, et al.) played by woodwinds and string instruments to 20 female nurses. Her results showed that the left ear was clearly more efficient at encoding music while the right ear processed spoken digits more effectively. These results strongly support the notion that the right hemisphere processes music while the left processes verbal material. Shankweiler (1966), using Kimura's (1964) tapes and materials, conducted the same tests except that the subjects this time were 45 patients with epileptogenic temporal lobe lesions, 21 of the left side and 24 of the right side. These patients were tested both

before and after unilateral lobectomies. Temporal lobectomy in the left hemisphere resulted in a significant reduction of accuracy of reporting digits but produced no change when the stimuli were melodies. After right temporal lobectomy the reverse was the case; increased errors in melody recognition occurred with no change in the efficiency of handling competing digits. Furthermore, left temporal patients showed a clear-cut superiority in recognition of melodies which arrived at the left ear as compared to the right temporal patients. Chase (1967) conducted a study similar to Shankweiler's (1966) using the Seashore items rather than digits and melodies, and obtaining the same results. More recently Gordon (1970) used 20 male college students as subjects to compare the encoding of melodies played on a recorder with the encoding of chords played on an electric organ on a dichotic listening task. He found a clear left ear preference for the chords but not for the melodies. A further confirmation of this result was obtained by Gordon and Bogen (1974). Administering intracarotid injections of sodium amylobarbitone to patients with transient hemiplegia, they found that "after a right carotid injection singing was markedly deficient, whereas speech remained relatively intact. Songs were sung in a monotone, devoid of correct pitch; rhythm was much less affected. By contrast, singing was less disturbed than speech after left carotid injection." In summary, it seems fairly well established that the pitch, timbre and melodic aspects of music are lateralized to the right hemisphere.

Visuo-spatial processing also seems to be lateralized to the right or non-verbal hemisphere. As early as 1941 Brain observed that lesions to the right hemisphere caused visual disorientation where the same kind of lesions to the left did not. Hecaen and Angelergues (1962) noted that of 18 patients with unilateral lesions followed by agnosia for faces 16 had right lesions and of the other 2 cases one patient was left handed. Bogen and Gazzaniga's (1965) excellent review discussed several studies in the area, as well as their clinical cases and concluded that, "These studies provide affirmative evidence of dominance in the minor (right) hemisphere for certain visuo-spatial functions." De Renzi, Faglioni, and Scotti (1970) further supported the notion with their observations that right hemisphere damaged patients were less able to visually and tactilely locate an object (a marble) in space than were left damaged patients. Lansdell (1970) also found that right temporal lobe removals negatively affected visual construction and closure performance while left removals did not. A finding from an unusual quarter, that of Kershner (1971), also supports the notion of right hemisphere specialization for visuo-spatial processing. He tested many first grade children on tasks involving conservation of space and found that children who were right handed and left-eyed performed better than other children. Finally, Kohn and Dennis (1974) examined four right and four left hemidecorticates and found that right hemidecorticates performed significantly poorer on both Porteus and WISC mazes than did left hemidecorticates, despite the fact that there were no differences in overall IQ scores.

It seems safe to accept the notion that language is predominantly processed by the left hemisphere and that some aspects of music, especially timbre, pitch and chords, and visuo-spatial information are predominantly processed by the right cerebral hemisphere. However, any account

of processing information must account for the attention to and selection of stimuli from an ambient environment full of potential sights, sounds, etc. Music does not just magically go in the left ear, verbal material simply in the right and the louder or more salient one gets processed. This is especially a problem in interpreting the results of dichotic listening studies. In her 1964 study Kimura demonstrates an awareness of the problem of attention when she notes that "throughout these tests the subject was discouraged from selectively attending to one ear." One wonders if the discouragement came via a verbal or spatial mode. Kinsbourne (1972, 1974, etc.) has developed a theory regarding the role both hemispheres play in the orientation to and selection of information to be processed. His basic idea is that a normal subject, expecting verbal information, would establish a "verbal set", the neurophysiological correlate of which would be the activation of the left hemisphere and the inhibiting of processes in the right hemisphere. This, all other things being equal and the processing being in general on a high level, will displace the subject's attentional bias to the right side of his visual field. Just the opposite case would obtain for a musical or spatial "set". Kinsbourne (1970) originally supported this idea with a study of tachistoscopically presented squares with breaks at the top, bottom, left side and right side to 32 subjects. When concurrent verbal activity was introduced into the experimental condition attention was seen to shift markedly to the right side of the visual field, resulting in fewer errors there than on the left. His findings have been corroborated both by studies of submotor attentional shifts in the visual field and by observations of overt motor behaviour. The essence of his model is that "While engaged in verbal thought, a person should visibly orient to the right, not in order to look at anything in that direction but as the involuntary accompaniment of the cognitive process. When he thinks about a spatial problem he should look leftward or up . . ." (Kinsbourne, 1974). Many studies of this phenomenon have been carried out since his 1970 work, and Kinsbourne's (1974) review is so concise that it is reproduced here:

1. Kocel et al. (1972). Using 16 males and 13 females and recording eye movement by video, they found more right eye movement on twenty verbal and numerical than on twenty spatial and musical questions.

2. Hiscock (1972). Using 12 males and 12 females and recording eye movement electronically, he found more right movement on five verbal than on five spatial questions.

3. Berman et al. (1973). Using 10 males and recording on video, they compared amount of right movement on musical questions with that on nine other sets of questions. Wechsler information, Wechsler vocabulary and numerical arithmetic questions gave significantly more right movement.

4. Weiden and Etaugh (1973). Using 24 male and 24 female subjects and recording on video, they found more right movement on 25 verbal and numerical than on 24 spatial and musical questions.

5. Gur (1974). Using 32 males and recording on video with the experimenter seated behind the subject, she found significantly more movement to the right on 20 verbal and to the left on 20 spatial questions.

(Kinsbourne, 1974, p. 279)

That visual attention, gaze aversion, and perhaps orientation in space seems to be directionally influenced by the activation of one cerebral hemisphere with a corresponding suppression of the other is extremely significant and potentially useful for a host of reasons (Bakan, 1975, and Erlichman, Weiner and Baker, 1974). More interesting theoretically is the concomittant notion that the attentional or orientational processes of one hemisphere may be activated to the exclusion of those processes in the opposite hemisphere. If one is sympathetic to the line of thinking about the role attention plays in developmental processes which has its roots in the writing of Husserl and Kant and is more recently elaborated by Piaget and Pascual-Leone one will immediately see the significance of this notion to understanding the development of autistic behaviour. The autistic child, just like any other child, from the onset of his functioning constructs mental units Piaget calls schemes and organizes those schemes into a complex hierarchical structure. At any point in development what stimuli can be perceived, attended to, or selected for information processing is codetermined by what schemes have been previously constructed and the information available in the environment at that moment. If cerebral processing was shifted to the right hemisphere at birth, (and that hemisphere maintained its normal function, not compensating and taking on the normal function of the left hemisphere), then both the content and the form of the mental structures constructed during development would conform to the limitations of that hemisphere.

A central point of my model is that autistic children are born with a cortical organization which is continually and predominantly biased towards processing information by the right hemisphere. If the kind of information which is normally processed by the right cerebral cortex is the chief content upon which the child builds a hierarchy of schemes and cognitive structures then it would follow that the only information a child would be capable of orienting to or assimilating would be right hemisphere information. If this were true then autistic children would be lacking the analytic aspects of language while retaining musical and visuo-spatial processing. That lack of both receptive and expressive language is a central symptom of autism is universally accepted (Rutter, 1974). The lack of ability to process language may have earlier and more pronounced effects than previously realized. Condon and Lander (1974) found that even very young infants react physically in synchrony with the speech patterns of adult caretakers. More recently Condon (1975) has discovered that autistic children react atypically to adult speech patterns. The work of Eimas (1971) has also suggested that normal infants are receptive to linguistic aspects of sound. If the autistic child is missing this information which is available to and normally used by very young normal infants (Condon even suggests that the processes may start before birth) one can imagine the subsequent isolation and frustration resulting therefrom.

While every worker in the field knows that autistic children are especially attracted to music there is little evidence of this in the literature (Hollander & Juhrs, 1974). There is also some evidence that autistic children do well on tasks involving spatial relations and form discrimination. Ritvo and Provence (1953) and Wing (1966) have reported autistic children to be equal or superior to normals in their capabilities with peg boards, Sequin form boards and puzzles. Hermelin and O'Connor (1965) also suggest that the kinaesthetic feedback system in autistic children is intact, based on data from tests requiring form and size discrimination. Lockyer and Rutter (1970) report that "autistic children score relatively well on tests of visuo-spatial function or memory." My own observations of autistic children in a clinical setting confirmed these findings. I often found their ability with puzzles, sand construction and water manipulations to be at par with chronological age expectations and sometimes advanced for their age levels.

In summary, there is a great deal of evidence supporting the notion that the left cerebral hemisphere processes language while the right processes music and visuo-spatial information, and ample evidence to suggest that autistic children do not perform left hemisphere functions and are often proficient at right hemisphere processes.

If autistic children are right hemisphere processors at birth, that state must be the result of an initial and developmental event. The mechanisms leading to cerebral dominance are far from being known but there are several hints available. For instance, Kinsbourne (1973 and 1975) reflects the suspicion of many researchers, that while it is normally the case that severe perinatal or prenatal damage to either hemisphere will result in compensation by the remaining intact hemisphere to the effect that the processes of the damaged part will be adopted therein, if the damage is too slight to activate the compensatory mechanism the overall brain organization will develop as it normally would, except that the specific functions associated with the damaged area would be impaired. This notion fits in well with that of Turkewitz (1972) and Hammer and Turkewitz (1974) who found not only that newborn infants responded more consistently to touches on the right side of their mouths and faces with turns to that side, than they did to touches on the left side, but also that babies who experienced perinatal problems and who scored poorly on the Apgar measures at birth did not show a clear preference for side of stimulation, and exhibited a much higher rate of confused responses than did the healthy babies. These studies and the very recent auditory studies of Witelson (1973) and Entus (1975) support the notion that this lateralization of function can be affected by biological factors during gestation and birth.

If cerebral processing is shifted to the right hemisphere at birth then either neurological damage suffered during gestation or birth or a genetic factor may be responsible for that displacement. Hansen (1976) has discussed at length the likelihood of early infantile autism being caused by polygenic transmission, a dominant rare gene mutation or early neurological damage. He rules out polygenic transmission as a possibility but allows that the high concordance rate among monozygotic twins permits speculation that a dominant rare gene mutation is responsible. It should be pointed out, however, that MZ twins have a higher risk of perinatal

difficulty than do DZ twins who in turn have a much higher perinatal risk than singletons. All of the data Hansen reviews leads him to suspect early neurological damage as the initiating event. This suspicion is reinforced by Finegan's (1976) recent study which found that low Apgar score, primary apnea, haemolytic disease and respiratory distress syndrome occurred at a significantly higher rate in newborn autistics than would be expected on the basis of the general population frequencies. Rutter (1977) has also suggested the possibility of polygenic transmissions with his finding of a higher than expected occurrence of language disorders in autistic families. It should be pointed out here that the genetic and pre- and peri-natal models of causation are not mutually exclusive. It is, of course, quite possible that a genetic abnormality expressed only in the autistic future could cause pre- and peri-natal difficulties.

Also of interest in speculating upon the causes of an early shift to right processing is the phenomenon, extensively reviewed by Harris (1975) of sex differences in the development of right hemisphere skills. Bakan's (1975) behavioural studies have suggested that males are more asymmetrical, either to the right or left, than are females. Lansdell (1964) also found a tendency for male brains, more often than female brains, to be without the small band of tissues which connects the two halves of the thalamus across the third ventricle. Lansdell and Davie (1972) suggest that this agenesis of the massa intermedia might be an advantage for the performance of some non-verbal tasks. These works, exemplifying investigations into the sex differences found in cerebral asymmetry, give rise to another avenue of speculation which is concerned with the correlation between the high (approximately 95 percent) incidence of male autistic children and such sex differences. Of interest in this respect also is the observation that many autistic children who exhibit no signs of any cerebral damage at birth experience epileptic type seizures later in life. This not only suggests the possibility of earlier undetected cerebral damage, but a kind of damage often associated with the integration of the two hemispheres. Of course, the possibility that the specific locations and types of brain damage associated with autism may well be as various as the presenting symptoms of the disorder, should not be overlooked.

The most concrete evidence for left hemisphere dysfunction in all autistics comes from the pneumoencephalographic studies of Hauser (1975) and the electrophysiological work of Tanguay (1976). From his finding that 88% of his autistic subjects demonstrated enlargement of the left ventricle Hauser (1975) speculates that medial temporal lobe disease is responsible for the autistic condition. Tanguay (1976) showed that normal children show larger evoked responses over the right hemisphere during REM sleep while no consistent hemispheric differences are found in autistic children. Most recently Colby and Parkison (1977) have found evidence to suggest that autistic children may have failed to develop the usual left hemisphere dominance. Among a sample of 20 autistic and 25 normal children, the frequency of non-right-handedness for the autistics was 65% whereas it was 12% for the normals. Failure to lateralize in the normal way is taken as a clinical indicator of brain damage. These authors speculate that some agent, such as a virus, may be responsible

for damage to a process of brain protein synthesis which could be essential for the acquisition for symbolic rules which underlie language as well as other functions.

Whatever the cause may be, it is important at this stage first to demonstrate that such a shift to right processing has occurred in the autistic child. If a shift to right cerebral processing does occur before or just at birth, then it would follow that the kind of information which is normally processed by the right brain is the chief content upon which the autistic child builds a hierarchy of schemes and cognitive structures; and it would follow further, that the only information a child so organized would be capable of assimilating and processing would be right hemisphere information. The result would be a hierarchically organized structure of non-verbal or spatial schemes which would process only nonverbal, musical or spatial information and virtually ignore language.

The following three studies are preliminary to an extensive series of experiments currently underway to test the notion that autistic children are right hemisphere processors.

EXPERIMENT I A

That autistic children and adults orient towards and spend a great deal of time listening to music is widely observed. One cannot help but be impressed by the follow up report of 11 autistic children who have made adequate social adjustments (Kanner, 1961) in which music played such a major role for 8 of the 11 subjects that the activity was spelled out in the very brief biographies reported. The specific hypothesis of the first study is that, given a free choice between music and verbal information, autistic children will predominantly choose music while normal children will choose verbal material.

Method

Subjects

Seven autistic children, 4 boys and 3 girls, with a mean age of 6-2 with a standard deviation of 5.8 months and 7 normal children, 4 boys and 3 girls, with a mean age of 5-1 with a standard deviation of 4.3 months, participated as subjects. The autistic children were institutionalized at Thistletown Regional Centre where they had been diagnosed autistic. The normal children were enrolled in the York University Day Care Centre.

Apparatus

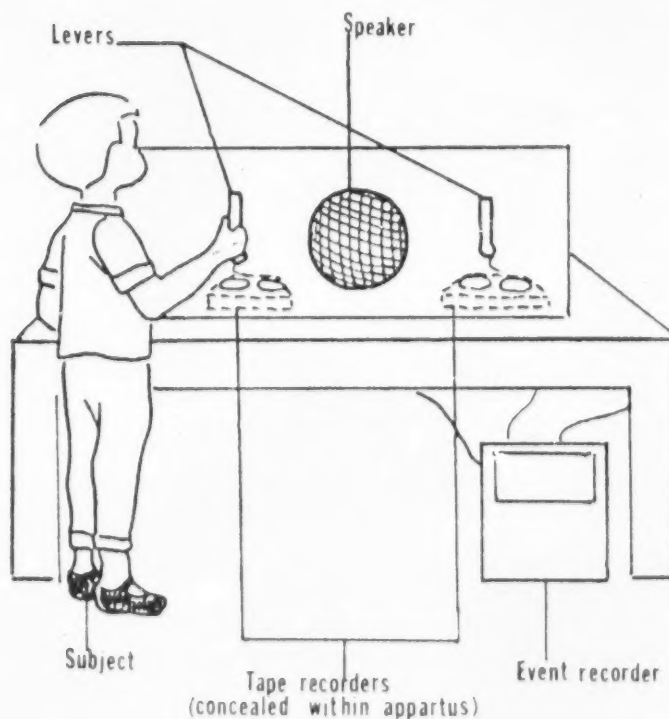
Each group was tested with an apparatus consisting of a wooden box measuring 2 feet x 3 1/2 feet x 2 feet with two springed levers flanking one 6" speaker mounted onto the faceboard. The levers were equipped with micro-switches connected to two model TC 60A Sony cassette-recorders and a four-channel event recorder. The device was constructed so that depression of a single lever activated the corresponding cassette-

recorder for a 5-second duration and switch off. If the lever was depressed again during the initial five-second current interval, the first cycle would be cancelled and replaced by another five-second current interval. Both levers were connected to a corresponding channel of the event recorder which marked each response.

Two pre-recorded 45-minute cassettes were used as the stimuli. The "Music" tape was composed of varied musical selections drawn from popular children, rock and classical sources. The "Speech" tape consisted of three children's stories, read by a female voice. A graphic representation of the experimental set-up is presented in Figure 1.

Figure 1

Experimental set up for experiments 1a and 1b



Procedure

The apparatus was set up in a small room familiar to the subject. Once seated in front of the box, the experimenter modeled its operation by pulling first one lever, listening to the subsequent tape and then repeating for the other lever. The next stage actively involved the subject by guiding his or her hand to a lever and repeating the operation of stage 1.

Following this brief orientation, a timer was set for fifteen minutes, the event recorder activated, and the subject was urged to pull either lever. At the end of fifteen minutes the tapes in each machine were exchanged and the subject was again urged to pull the lever(s) of his or her choice. After another fifteen minutes the session was terminated.

All subjects were tested for three thirty minute sessions over the course of two weeks. The sessions were conducted at varying points of the day, geared to disrupt cottage or day care routine minimally, but were otherwise identical in their procedure. The initial positioning of the tapes (e.g., music - left lever; speech - right lever) was chosen randomly throughout the three sessions.

Results

Each subject pulled levers well over 500 times during the course of the study. The percent of pulls for each lever and for each kind of stimuli was calculated for each subject. The mean percentages are presented in Table 1. The mean frequencies were calculated for each lever and for each group and submitted to a chi-square analysis. For the group by lever test $\chi^2 = .158$; d.f. = 1 and $p > .05$. For the group by sound test $\chi^2 = 16.26$; d.f. = 1 and $p < .001$. It is clear that the autistic children preferred music while normal children preferred the verbal information.

Table 1a

Percent of Total Pulls According to Group and Lever

	<u>Left lever</u>	<u>Right lever</u>
Autistic	44.1	55.9
Normal	41.3	58.7

Table 1b

Percent of Total Pulls According to Group and Type of Sound

	<u>Music</u>	<u>Verbal</u>
Autistic	62.8	37.2
Normal	34.3	65.7

EXPERIMENT I B

This study was very much like the first except that some procedures were refined and the content of the tapes was changed.

Method

Subjects

Ten autistic children, 7 males and 3 females, with a mean age of 9-4 with a standard deviation of 10.2 months and 10 normal children, 5 males and 5 females, with a mean age of 8-2 with a standard deviation of 4.7 months, participated as subjects. Six of the autistic subjects were institutionalized and 4 were living at home. The normal subjects attended an elementary school in the Borough of York in Toronto.

Apparatus and Material

The apparatus was similar to the one used in Experiment Ia except that the levers were positioned further apart so that both could not be pulled simultaneously, a problem encountered in the first study. The content of the tapes was also changed. One tape contained excerpts of 10 common songs with each excerpt lasting 15 seconds, all of which were sung by a female researcher. The second tape contained the same lyrics as the excerpts on the first tape but this time they were spoken in a normal way by the researcher, rather than sung. Of course, each pull of the lever activated the tape for about 15 seconds. Any pulls of the lever during the 15 seconds during which the tape was playing had no effect.

Procedure

The procedure was identical to that in Experiment Ia, except that each subject was tested for only one 45-minute session of three 15-minute segments.

Results

The percent of pulls for each kind of sound was calculated for each subject. The mean percentages according to group and sound are presented in Table 2. The mean frequencies were analyzed with a resulting $\chi^2=23.39$, d.f. = 1 and $p < .001$. It is clear that autistic children preferred the sung version while normal children showed no preference.

Table 2
Percent of Pulls According to Kind of Sound in Experiment 1b

	<u>Songs sung</u>	<u>Songs spoken</u>
Autistic	76.8	23.2
Normal	43.3	56.7

EXPERIMENT II

This study was designed to be a more direct and rigorous test of the notion that autistic children are right hemisphere processors and that this lateralized processing is not only responsible for a slight shift in spatial orientation and attention but for information selection and orientation as well. Three specific hypotheses were tested:

1. That, given a free choice, autistic children will orient towards and listen to musical more than to verbal information, while normal children and adults will orient towards and listen predominantly to verbal information; 2. That, given a free choice, autistic children will listen to all information predominantly with the left ear while normal subjects will listen to musical information with the left ear and verbal information with the right; and, 3. That autistic subjects, given a choice between harmonic, melodic and rhythmic music, will listen to one type more than another and, given a choice between poetry, spoken Russian and a spoken English story, will listen to one type of verbal material more than another and that the preferences of the autistic subjects will differ from those of normal subjects. Confirmation of the first hypothesis will further confirm the results of Experiments Ia and Ib. If the second hypothesis is supported by the results, Kinsbourne's notion of attentional effect of lateralization of processing will be extended to the auditory model and the first concrete evidence of asymmetrical lateralization in autistic subjects will be obtained. The third hypothesis should be considered more exploratory than as a test of a specific notion.

Method

Subjects

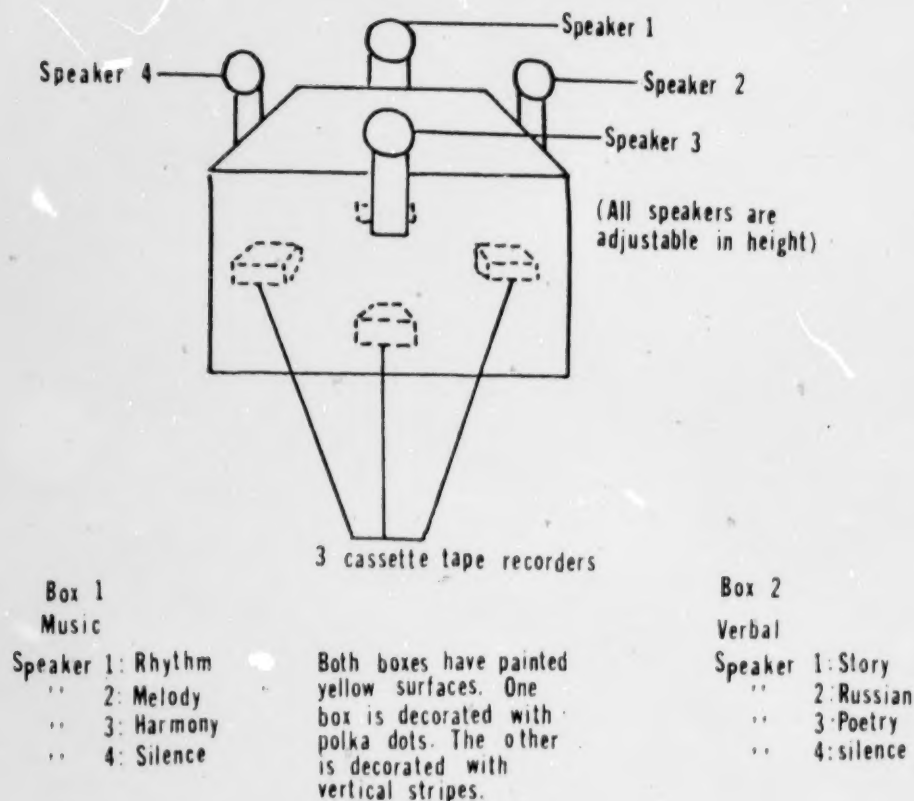
Two groups of subjects participated in this study. The first group consisted of 11 autistic children attending a summer day camp for autistic and retarded children. There were 8 males and 3 females in this group with a mean age of 10.3 years and an S.D. of 2.2 years. The second group consisted of 25 normal children and adults. The normal children were either faculty children or enrolled at the York University Daycare Centre. The normal adults were undergraduates at York University. There were 7 children, 4 males and 3 females with a mean age of 5.4 years and S.D. of 1.4 years and 18 adults, 11 males and 7 females with a mean age of 19.1 years and an S.D. of 1.1 years. An effort was made to determine the hand and foot preferences of all subjects. All of the normal subjects reported that their hearing was unimpaired.

Apparatus and Materials

Two wooden boxes (see Figure 2) were designed for this study. To each of the four sides of each box was attached a small speaker which was adjustable in height. There were, therefore, four speakers on each box, or eight speakers in all. Three of the speakers on each box were connected to cassette tape recorders concealed within the box;

Figure 2

Detail of boxes used in experiment II



one speaker was connected to nothing. The boxes were painted yellow and each of the eight vertical sides was marked brightly and distinctively with brightly coloured tape. A twenty pen Esterline Angus event recorder was used to collect the data. It was connected to a panel of 16 buttons, one pair for each speaker to represent the left and right ear of the listening subject.

The six audio tapes were composed of the following sounds:

Music. Three tapes consisted of excerpts of contemporary music composed and performed by Pink Floyd, Yes and Chicago. One of these tapes contained passages chiefly melodic in content, usually long solo passages on electric guitar or some keyboard instrument including a variety of synthesizers. A second tape contained rhythmic passages fea-

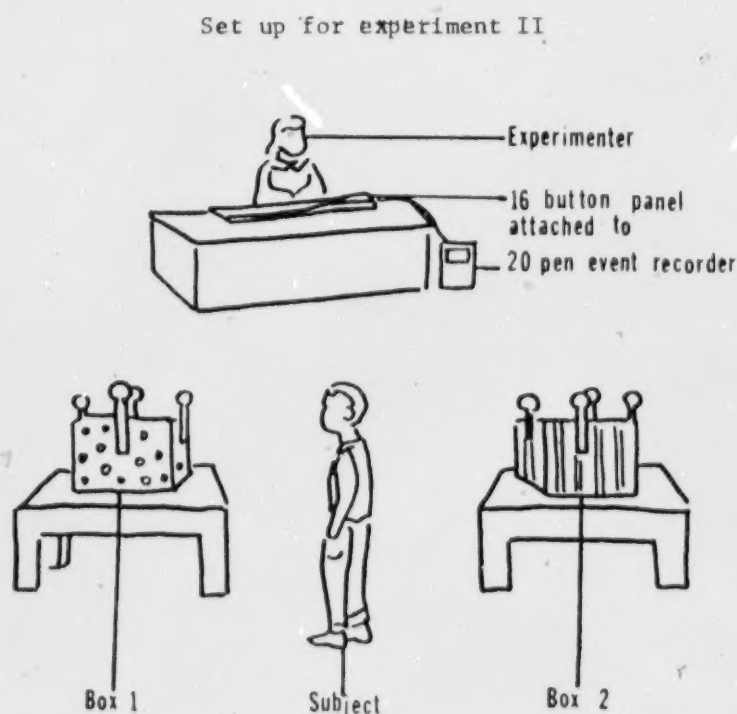
turing various percussion instruments. A third tape consisted of harmonic passages in which rhythm and melody were fairly well obscured in slow mixes of several instruments. While none of the three "aspects" of music could be totally isolated the quality of the sound as determined by compositional skill and musicianship was controlled by ensuring that music from any one group was used on all three tapes.

Verbal. One tape consisted of a female researcher reading a popular children's story. A second tape contained poetry written and read by Dylan Thomas while a third tape consisted of a Russian history lesson read in Russian.

Procedures

The boxes were placed in the centre of an otherwise empty room, as shown in Figure 3. The experimenter brought the child to the room

Figure 3



and showed him each speaker. E listened at each speaker, randomly alternating ears, and then directed S to listen, making certain that S listened for a few seconds at each of the speakers. E then sat down at a desk with a panel of buttons, and recorded S's behaviour at the speakers. There were three 15-minute sessions for each child with a three minute rest period between each session. E changed the location of the tapes within each box, and switched the location of the boxes

during this rest period.

Results

The amount of time each subject spent listening at each speaker and with which ear he listened was recorded on an event recorder. The total time spent listening was calculated as well as the percentage of that time spent at each kind of sound and with which ear. The group means of these percentages are graphically represented in Figure 4. These mean percentages of listening time were collapsed across three types of music and the three types of verbal information and these results are graphically represented in Figure 5. The data were further analyzed by obtaining a difference score for each subject in each condition by subtracting the percent of listening time with the right ear

Table 3

Mean Differences Between Left and Right Ear Listening (time spent listening with left ear minus time spent listening with right ear) for Autistic and Normal Subjects on All Tasks.

	<u>Variable</u>					
	Melody	Harmony	Rhythm	Story	Russian	Poetry
Normal	1.10*	1.05	1.56	-6.63**	-1.18	-6.63
Autistic	23.73*	9.55	10.00	5.46**	3.91	0.91

* the difference between these scores of difference is significant at the .01 level.

** the difference between these scores of difference is significant at the .02 level.

from the percent of listening time with the left ear. Means were obtained for normal and autistic subjects according to the type of auditory stimulation and these are presented in Table 3. These difference scores were analyzed by an analysis of variance using Wilks lambda criterion and a canonical correlations test of roots. The difference scores between normal and autistic subjects were compared across the six auditory variables. The analysis of variance revealed a significant effect for melody ($F=5.39$; d.f. = 1,33; $p < .027$), and for the story ($F=7.17$; d.f. = 1,33; $p < .011$). In the condition in which the content was Russian language the difference between the autistic and normal subjects approached significance ($F=3.86$; d.f. = 1,33; $p < .058$). A summary of the analysis of variance appears in Table 4.

Mean percentages of listening time according to group
(normal and autistic) and ear (left and right)

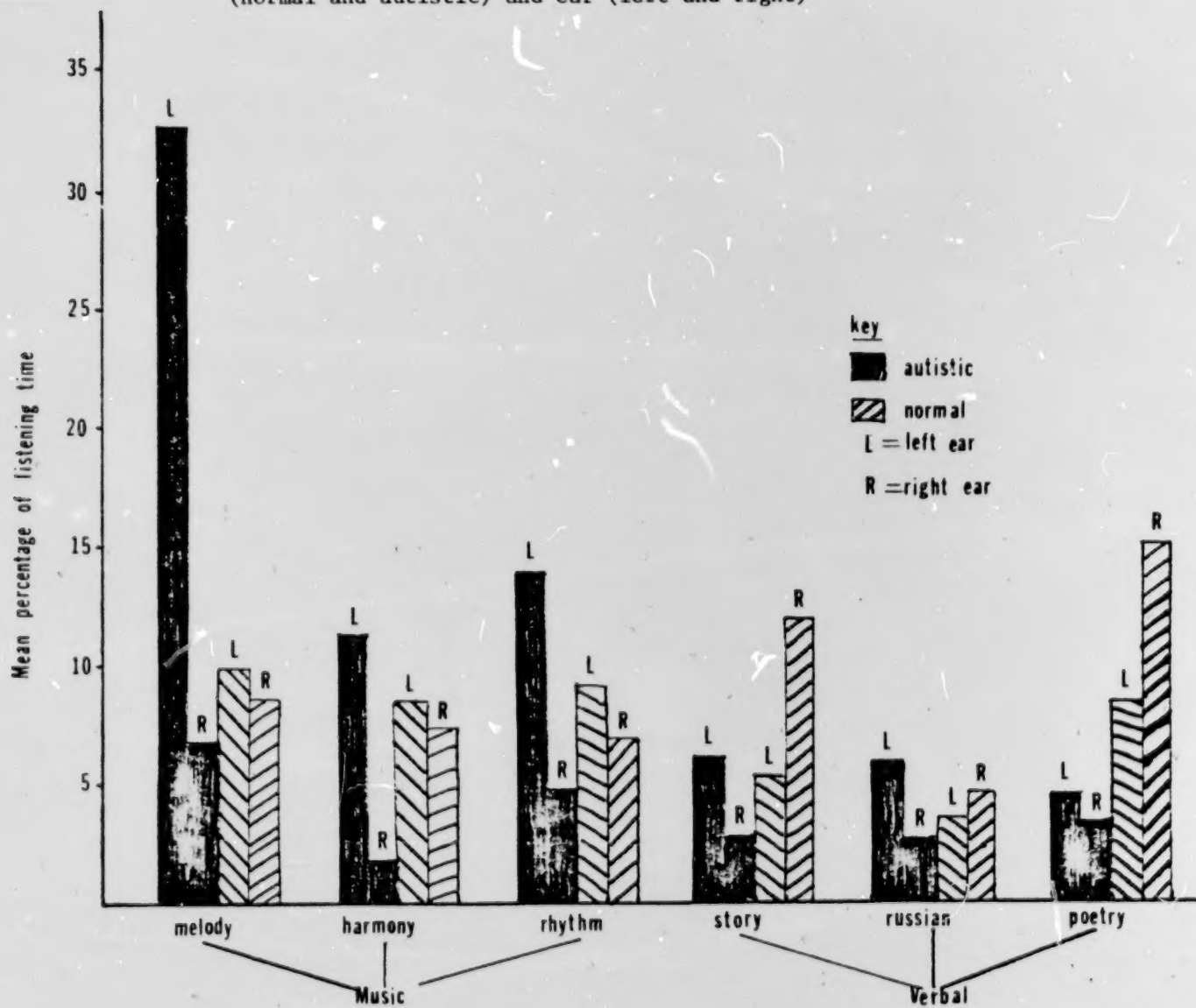


Figure 4

Figure 5

Mean listening time collapsed across musical and verbal subcategories

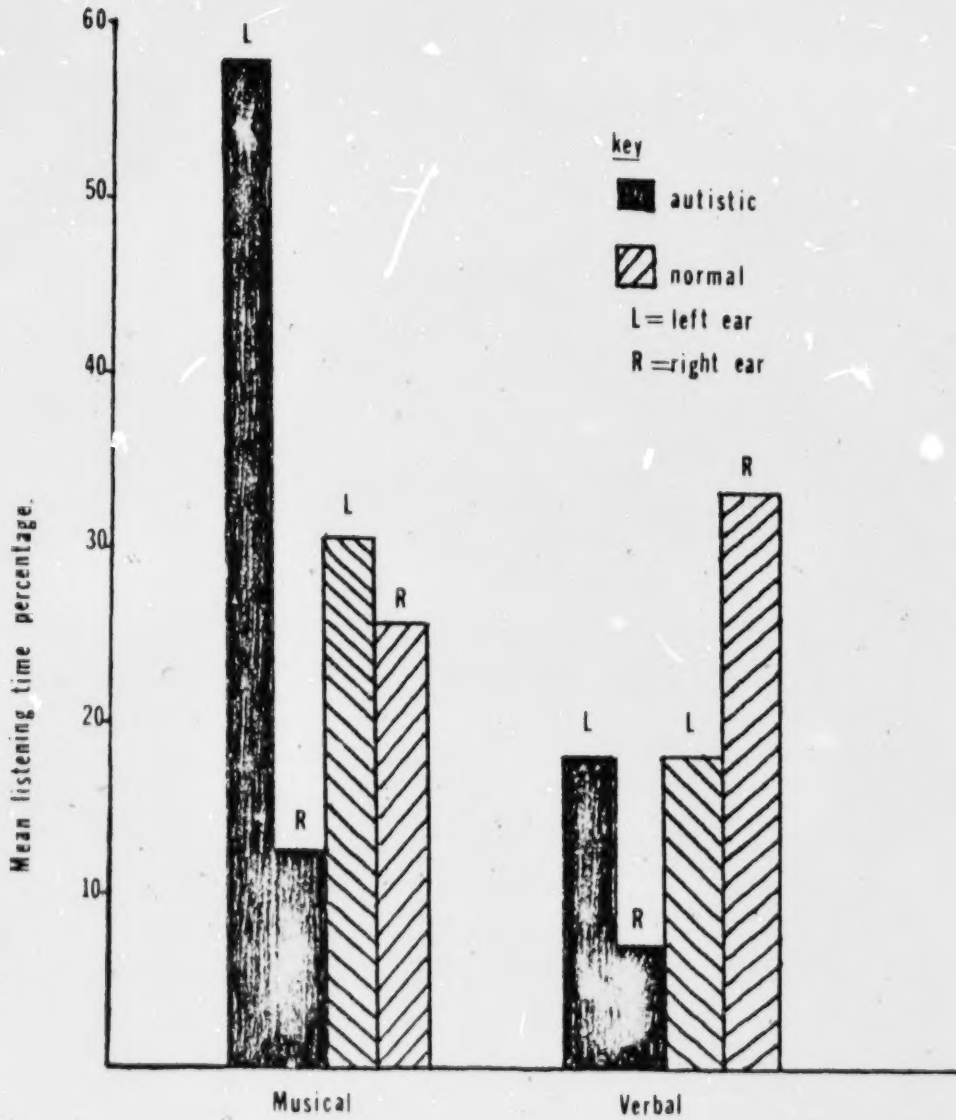


Table 4

Summary of Analysis of Variance of the Differences Between Right and Left Ear Listening On All Tasks for All Subjects (N = 35).

<u>Variable</u>	<u>Mean Sq.</u>	<u>F(1,33)</u>	<u>P less than</u>
Melody	3859.1	5.39	.02
Harmony	544.9	1.91	.17
Rhythm	537.5	1.70	.20
Story	1101.4	7.17	.01
Russian	195.3	3.86	.06
Poetry	428.6	1.53	.23

It is clear from these results that the autistic subjects oriented predominantly toward musical information and listened most of the time with their left ears. The normal subjects demonstrated a greater variation between themselves but the data as shown in Figures 4 and 5 gives tentative support to the notion that music is more likely to be listened to with the left ear and verbal material with the right.

Discussion

The results of both Experiments Ia and Ib and Experiment II lend support to the notion that some of the children who are diagnosed autistic are predominantly right hemisphere processors. The data encourages one to pursue the idea with empirical studies designed to test more precisely the hypotheses that the right cerebral hemisphere in autistic children is extremely more active than the left hemisphere and that the kind of cognitive processes an autistic child possesses are those associated with the right hemisphere. If the general model presented above is correct then the implications for models of normal development as well as the diagnosis and treatment of autism are great.

In the past decade a great deal of interest has focussed on the question of what role language plays in the development of normal cognitive development. A prominent approach to this question, pioneered by Furth (1969, etc.) was to search for humans who did not have language but developed the ability to think nonetheless. The extensive studies with the deaf seemed to eloquently make the point that language was not necessary for conceptual development until a careful analysis showed that the deaf do indeed have a language that can be every bit as efficient as any other natural language and that the better a child's ability with sign language the less developmentally retarded he is. Of course, all of the work with the deaf is valid if instead of talking about the effect of language on the development

of thought we talk about the effect of speech on thought. In the autistic child we have the unique opportunity to observe humans who have speech but who do not have language. Whether or not it is due to any cerebral asymmetry, many writers now agree that autism is primarily a disruption of the ability to comprehend and produce language as communication (Bartolucci, 1975; Rutter, 1968). It is widely observed that many of these children who do not have language are not retarded. If one could approach these children with somewhat the same sensitivity that modern ethnoscientists are approaching other cultures (Cole, Gay, Glick and Sharp, 1971) in search of similarities and differences in cognitive processes, a great deal of insight might be had into the role language plays in normal cognitive development. It will be quite interesting to see if the cognitive processes of autistic children are more different than they are deficient!

The implications of the model presented for the diagnosis of autism are quite complex and far reaching. On the simplest level, if autism is a result of exclusive right hemisphere processing, then a child suspected of being autistic need only be tested for asymmetrical lateralization of processing for diagnosis to be confirmed. On a deeper level, the model calls into question the validity of former conceptualizations of autism and the association made with childhood schizophrenia and other forms of emotional disorders. It may be the case that a new category needs to be constructed to separate children whose central problem is a central language disorder from those with primary emotional problems.

Conceiving of autism as primarily a central language dysfunction which is the result of an asymmetrical shift in cerebral processing demands a reconstruction of the goals of any treatment programme. While it is a difficult notion for many to accept, one must be prepared to consider the possibility that making autistic children as much like normal children as possible may not be the best strategy from the viewpoint of the well being of the child himself. While it is important to eliminate and control extremely disruptive behaviour, it may be as, or more, important to make certain that autistic children develop their cognitive and perceptual processes as fully as possible. Surely any attempt at normalization and socialization could only be facilitated thereby.

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